SEYMOUR

Design for a Steel Grand Stand

Civil Engineering
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DESIGN

FOR A

STEEL GRAND STAND

BY

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THESIS

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U N I V E R S I T Y   O F   I L L I N O I S

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This is to certify that the thesis prepared under the immediate supervision of Instructor C. W. Malcolm by

CLAUDE HENRICKSON SEYMOUR

entitled DESIGN FOR A STEEL GRAND STAND

is approved by me as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering

Ira O. Baker.

Head of Department of Civil Engineering

Introduction.

The object of this thesis is to design a steel grand stand which will have a seating capacity of about 3,000 or 3,500 people. It is to be designed for Illinois Field at the University of Illinois. As the field is very level, no contour map need be made.

A few years ago grand stands built entirely of steel were not at all common, but today several large driving parks already have, or are contemplating, large steel grand stands. The first one of large dimensions was erected at Monmouth, New Jersey. It was designed by Mr. F. S. Williamson, and is 700 feet long, 210 feet wide, and will accommodate 10,000 people. The stand was completed March 1, 1890. It is notable for its size and its cantilever roof, which projects 75 feet to the front and 25 feet to the rear of the main structure. Another grand stand erected at Yonker's, New York, for the Empire City Trotting Club, has a capacity of 7,700. It is 70 feet high, 400 feet long, and 90.5 feet wide over all. The cost was $100,000. This stand also has a cantilever roof, which projects 25.5 feet to the front and 15.5 feet to the rear. The largest and most costly structure of this type ever constructed is at the Belmont Driving Park, on Long Island, near New York City.

It is 116 feet wide, 650 feet long, and 55 feet high, and has a seating capacity of 11,000 people. There are 4,500,000 pounds of steel in the structure and the total cost was $450,000.

The Design.

Ketchum's "General Specifications for Steel-Frame Mill Buildings" was used in this design. A dead or minimum snow load of 10 pounds per square foot horizontal projection was used. The maximum snow load w s taken as 20 pounds per square foot, horizontal projection. The wind load was obtained from a curve based on Duchermin's formula, considering the wind force as 30 pounds per square foot, vertical projection, which gave 20 pounds per square foot, normal projection, for the flatter pitch, and 27.5 pounds per square foot for the steeper. The roof trusses were designed to take the maximum stress occasioned by the maximum wind and the minimum snow, acting at once; or the dead load and the maximum snow load taken together. The writer decided that it would not be necessary to consider the maximum snow and the maximum wind acting together, as this condition would never be obtained. The wind load on the seats was taken as 20 pounds per square foot, vertical projection.

The allowable unit tensile stress was taken as 10,000 pounds per square inch, on the net section. The allowable unit compressive stress used was

$$16{,}000 - 70\frac{l}{r} ,$$

where $\underline{l}$ = length of member in inches, center to center of end connections,

$\underline{r}$ = least radius of gyration of member in inches.

The shearing stress of the rivets was taken as 11,000 pounds per square inch, and the bearing value as 22,000 pounds per square inch. Field riveting was considered two thirds as efficient as shop riveting, and was avoided where possible.

Slag concrete was used for the steps, instead of crushed stone concrete, to reduce the weight as much as possible. Its weight was taken as 100 pounds per cubic foot. The dead load of the seats, including concrete, angles, plates, corrugated iron, lumber, etc., was taken as 35 pounds per square foot, horizontal projection. The live load, considering the weight of the average person as 150 pounds, was 32 pounds per square foot. The total load as calculated =67 pounds per square foot. The seats and seat trusses were designed for a total load of 75 pounds per square foot.

The roof trusses are fixed in the rear by the seat trusses, consequently there is no bending moment in the

front posts. The latter are spaced at intervals of 50 feet, in order to obstruct the view as little as possible. The intermediate roof trusses, which are spaced at 16 feet 8 inches, are supported by trusses four feet deep, and are connected to the front posts. The cantilever roof, which projects 10 feet in front of the main roof, is to protect the persons in the front row of seats from inclement weather.

The unsymmetrical roof, rather than the symmetrical roof, was used to better allow the use of the cantilever roof in front, and at the same time to give a more pleasing appearance. It was decided that it would be better to make the roof comparatively low, and thus avoid large wind stresses and correspondingly large truss members and footings. The writer considered that it was better to do this, although by so doing the occupants of the last few rows of seats could not see any higher than the level of the seats, which is about 25 feet.

The tendency of the wind to overturn a structure of this kind is very great, especially when there are no people in it. Comparatively large footings must be used to overcome this tendency, the largest of these being under the front intermediate seat trusses. When the wind is acting from the front, these footings are subjected to a large overturning force acting in a slightly upward direction and to the rear, with no appreciable load to resist

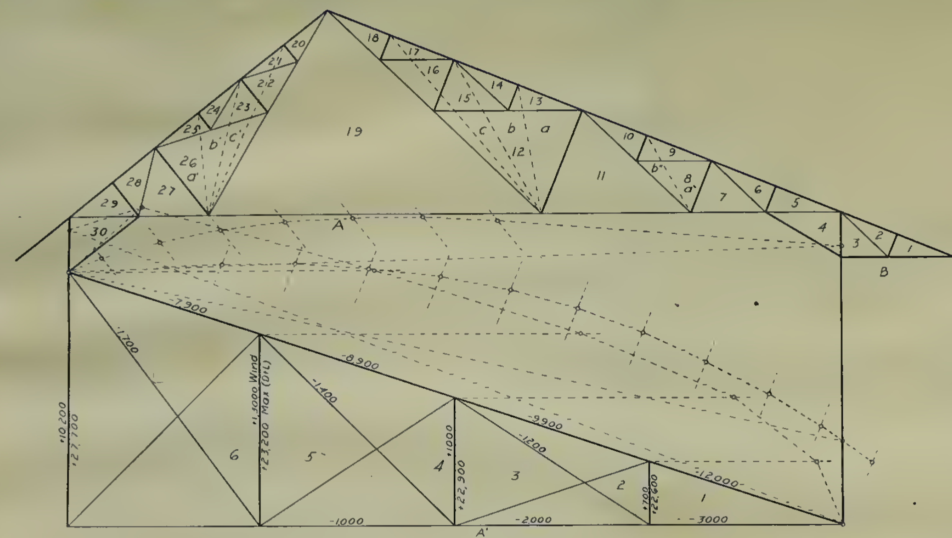
this force except the weight of the footings themselves. This accounts for the peculiar form of footing used at these places (see plate containing Details for Grand Stand).

The stresses were all obtained by graphic methods, and were scaled to the nearest 100 pounds. See Stress Sheet for stress diagrams and table of results.

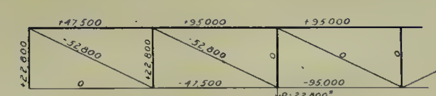
Weight and Cost.

There are 395,700 pounds of metal used, exclusive of the corrugated iron and the gas pipe. The structure contains 102,200 pounds of galvanized corrugated iron, 1,940 feet of gas pipe, 293 yards of concrete, and 26,290 feet of lumber. The estimated cost of the grand stand complete is $21,700.00.

The following four plates give the stresses, details, general plan and elevation, and a perspective of the completed structure.



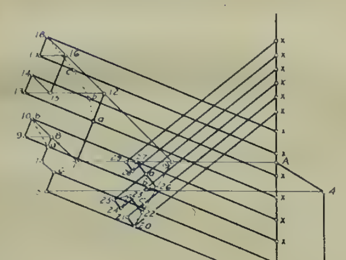
Roof and Seat Trusses



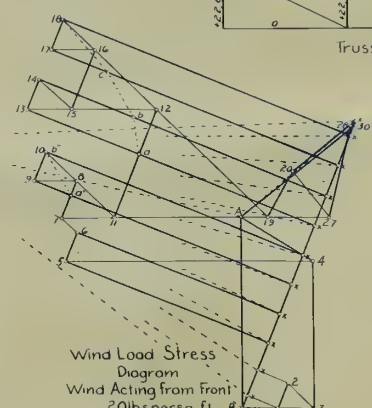
Truss Between Front Posts.

Stresses in the Roof Truss

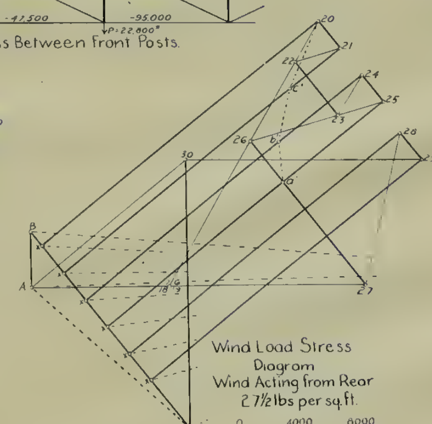
Name of Piece	Dead Load	Snow Load	Wind Load Front	Wind Load Rear	Dead + Max Wind Load	Dead + Snow Load
B-A	+7600	+15200	+12600	-3666	+22200	+22800
B-1	+1100	+2200	+2400	0	+3300	+3300
B-2	+2100	+4200	+1000	0	+6200	+6300
X-1	-1200	-2400	-2200	0	-3400	[illegible]
X-2	-1500	-3000	-2200	0	-3700	[illegible]
X-5	+11300	+22600	+14300	+9900	+25600	+33900
X-6	+10900	+21800	+14300	+9900	+24400	[illegible]
X-9	+12200	+24400	+15400	+9900	+30200	[illegible]
X-10	+11900	+23800	+18400	+9900	+30300	[illegible]
X-13	+12300	+24600	+20600	-9900	+32900	[illegible]
X-14	+11900	+23800	+20600	-9900	+32300	[illegible]
X-17	+11600	+23200	+20600	-9900	+32200	+34800
X-18	+11200	+22400	+20600	-9900	+31800	[illegible]
X-20	+8200	+16400	+5100	+23700	[illegible]	[illegible]
X-21	+8500	+17000	-5300	+23700	+32200	+25500
X-24	+9000	+18000	-3300	+23700	+32700	+27000
X-25	+9300	+18600	-3300	+23700	+33000	+27900
X-26	+8200	+16400	-400	+23100	+31300	+24600
X-29	+8600	+17200	-400	+23100	+31700	[illegible]
X-30	+6300	+13000	-300	+17600	+24100	[illegible]
1-2	+800	+1600	-1600	0	[illegible]	+2400
2-3	-1100	-2200	-2400	0	[illegible]	[illegible]
3-4	+6400	+12800	-3700	+2600	[illegible]	[illegible]
4-5	-12600	-25200	+16500	-9200	[illegible]	[illegible]
5-6	+900	+1600	+2100	0	+3000	[illegible]
6-7	-600	-1200	-1400	0	-2000	[illegible]
7-8	+1200	+2400	+2600	0	-3800	[illegible]
8-9	-1200	-2400	-2600	0	-4000	[illegible]
9-10	+900	+1800	+2100	0	+3000	[illegible]
11-10	-2800	-5600	-6300	0	[illegible]	[illegible]
11-8	-1600	-3200	-3500	0	[illegible]	[illegible]
11-12	-3300	-6600	-7600	0	-9900	[illegible]
12-13	-3700	-7400	-8700	0	-12400	[illegible]
13-14	+900	+1800	-2100	0	+3000	[illegible]
14-15	-1200	-2400	-2900	0	[illegible]	-3600
12-15	2400	4800	-5800	0	-8200	-7200
15-16	+1800	-3600	-4200	0	-6000	[illegible]
16-17	-1200	-2400	-2900	0	[illegible]	[illegible]
17-18	+900	+1800	+2100	0	-3000	[illegible]
20-21	+500	+1000	0	-2300	-2800	[illegible]
21-22	-700	-1400	0	-3100	[illegible]	[illegible]
22-23	+1000	-2000	0	-4600	[illegible]	[illegible]
23-24	-700	-1400	0	-3100	-3800	[illegible]
24-25	+500	-1000	0	+2300	[illegible]	[illegible]
26-25	-2000	-4000	0	-9200	[illegible]	[illegible]
26-23	-1300	-2600	0	-6100	[illegible]	[illegible]
26-27	+1500	-3000	-3900	+2100	[illegible]	[illegible]
27-28	-400	-8000	-6200	-6300	[illegible]	[illegible]
28-29	+500	-1000	0	-2300	[illegible]	[illegible]
29-30	-6700	-13400	-300	-3300	[illegible]	[illegible]
19-12	-4300	-8600	-10200	0	[illegible]	[illegible]
19-16	-6800	-13600	-6000	0	[illegible]	[illegible]
19-18	-8000	-16000	-8900	0	[illegible]	[illegible]
19-20	-3400	-6800	-3300	-20200	[illegible]	[illegible]
19-22	-2700	-5400	-3500	[illegible]	[illegible]	[illegible]
19-26	-1400	-2800	-3500	-10900	[illegible]	[illegible]
A-4	+2500	-5000	[illegible]	0	[illegible]	[illegible]
A-7	-10600	21200	[illegible]	-9200	[illegible]	[illegible]
A-11	-9000	-18000	[illegible]	-9300	[illegible]	[illegible]
A-19	-4700	-9400	+1600	-9400	[illegible]	[illegible]
A-27	-6300	-12600	-3900	-22200	[illegible]	[illegible]
A-30	0	0	[illegible]	[illegible]	[illegible]	[illegible]



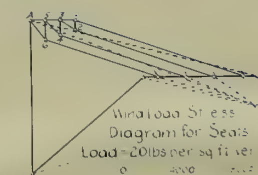
Dead Load Stress
Diagram
Dead Load 10 lbs per sq ft Hor Proj
Snow Load 20 lbs. per sq ft Hor Proj.
0 4000 8000



Wind Load Stress
Diagram
Wind Acting from Front
20 lbs per sq ft
0 4000 8000



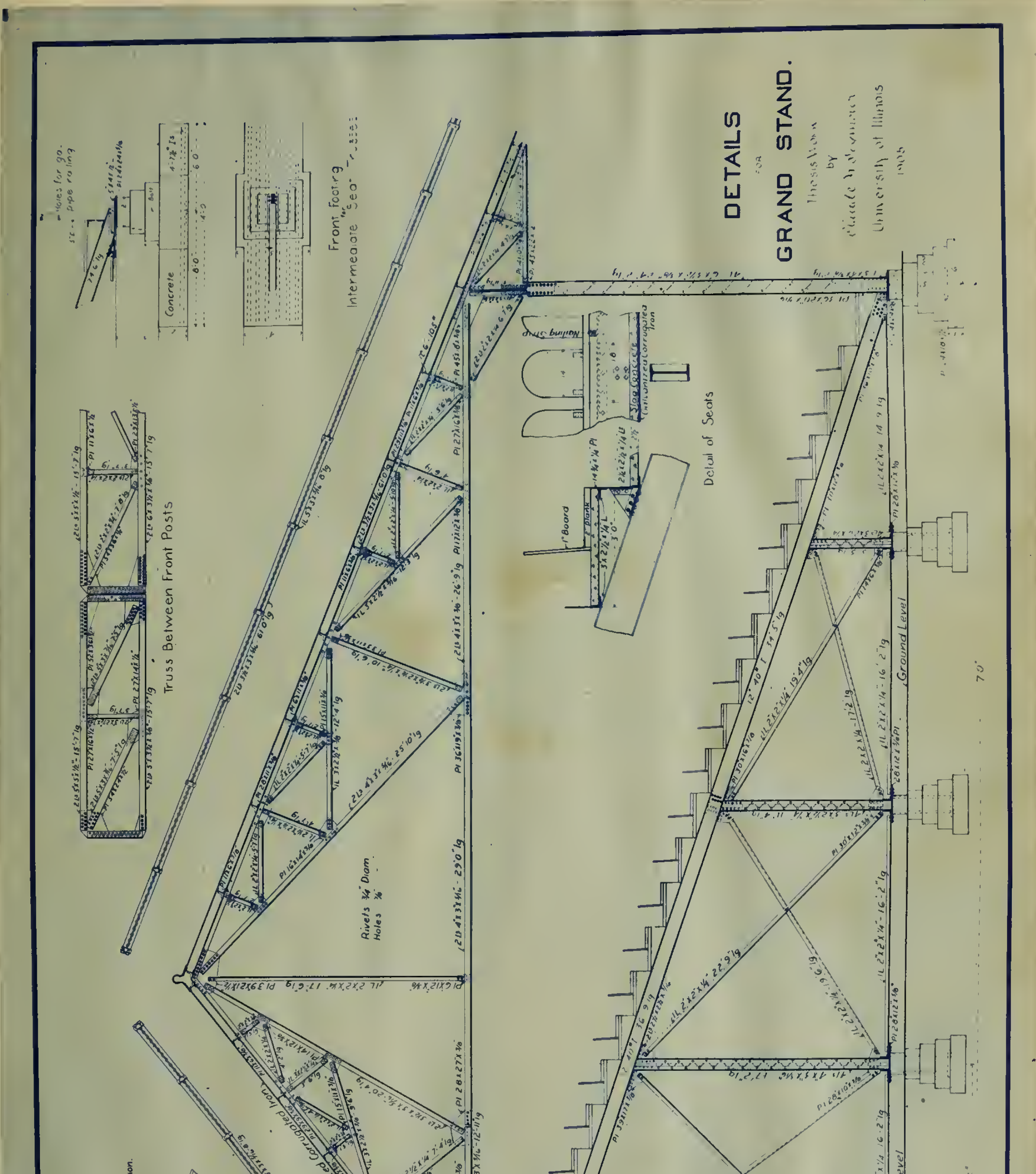
Wind Load Stress
Diagram
Wind Acting from Rear
$27\frac{1}{2}$ lbs per sq. ft.
0 4000 8000

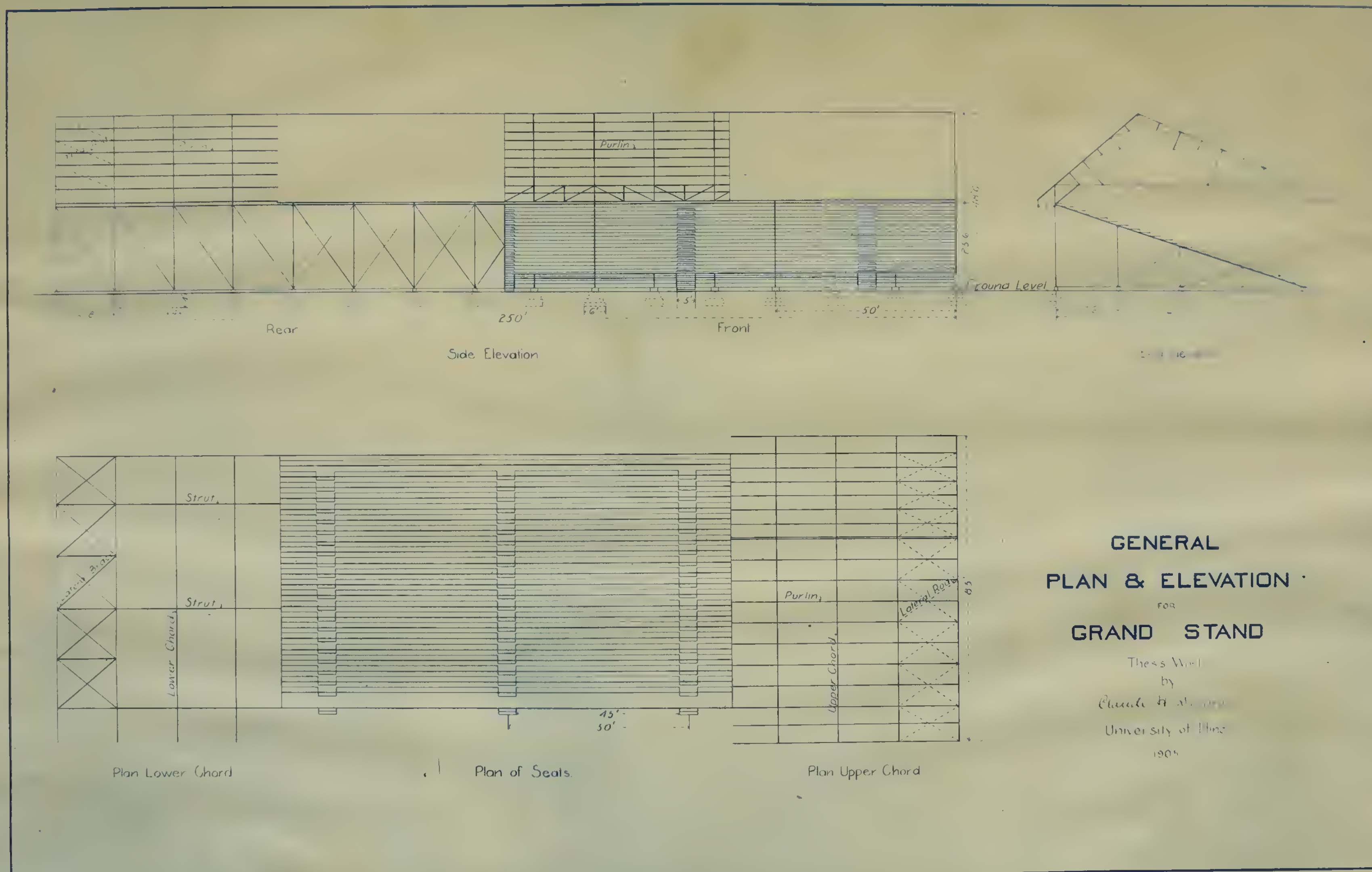


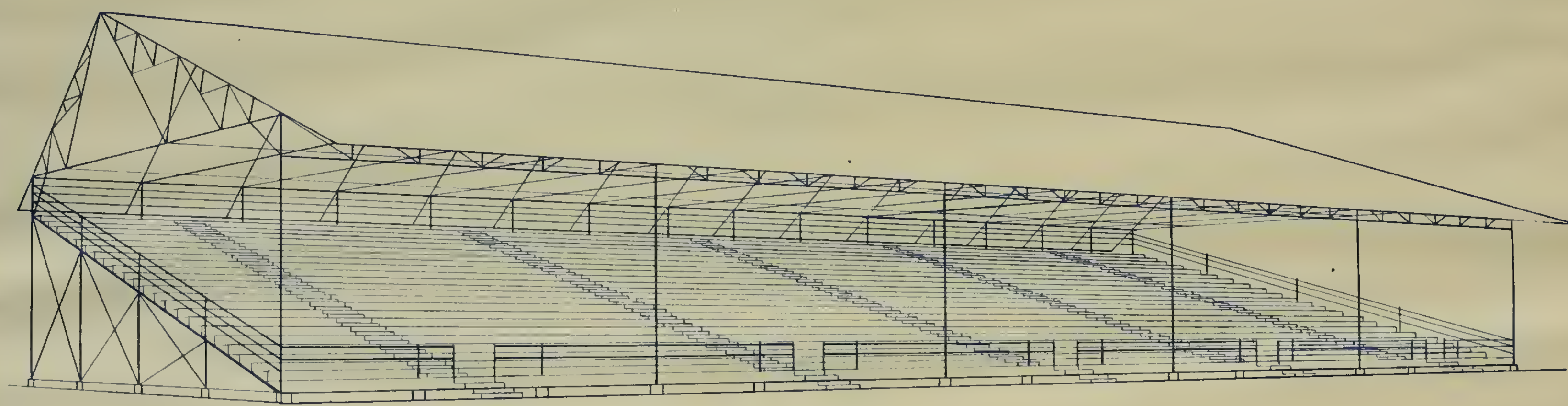
Wind Load Stress
Diagram for Seats
Load = 20 lbs per sq ft Ver Proj

STRESS SHEET
FOR
GRAND STAND

Thesis Work
by
Claude H. Seymour
University of Illinois
1905


DETAILS
GRAND STAND.
University of Illinois
Truss Between Front Posts
Front Footing
Concrete
Detail of Seats
Slag Concrete
Galvanized Corrugated Iron
1" Board
Rivets 3/4" Diam
Holes 13/16"
No 16 US SG Galvanized Corrugated Iron
Detail of Rear Post Connection.
Ground Level
Ground Level
70'


Purlin
Ground Level
250'
50'
Rear
Front
Side Elevation
Strut
Strut
Lower Chord
45'
50'
Purlin
Upper Chord
Lateral Rods
85'
Plan Lower Chord
Plan of Seats
Plan Upper Chord
GENERAL
PLAN & ELEVATION
FOR
GRAND STAND
by
1905



PERSPECTIVE FOR GRAND STAND

Thesis Work

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